

## Parameters Influence Pedestrian Traffic Safety at Urban Unsignalized Intersections

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### Abstract

This paper reports on diagnostic parameters for pedestrian traffic safety problems using the Traffic Conflict Analysis Technique (TCT), particularly for pedestrian crossings at urban unsignalized intersections. The method of study is based on the U.S. FHWA-Federal Highway Administration guides for vehicular and pedestrian conflicts, applied using data collected from pedestrian crossings of several types observed in 4 critical unsignalized intersections in Baghdad city all of them located on the CBD area and experiencing high vehicular and high pedestrians volumes.

Regression analyses is performed to relate hourly pedestrian conflict to (hourly traffic conflict, hourly pedestrian volume, average pedestrian walking speed) as well as hourly pedestrian conflict/ approach to (average spot speed, average pedestrian delay and approach width). HCM 2000 manual are adopt to determine the average pedestrian delay. Specific categories of countermeasures in geometric characteristics are suggested to improve pedestrian safety.

A developed model shows that, an extra increase of hourly pedestrian conflict can be represented by positive exponential model trend in relation with hourly pedestrian volume, hourly traffic volume, average spot speed and average pedestrian delay with coefficient of correlation range between 0.824–0.949, as well as a developed model shows that, an extra decrease of pedestrian conflict can be represented by negative exponential model trend in relation with average pedestrian walking speed with coefficient of correlation 0.921, on the other hand, it is found that, an increase of pedestrian conflict can be represented by positive linear model trend in relation with approach width with coefficient of correlation 0.837. In addition it is found that the higher coefficient of correlation 0.943 well get it when pedestrian conflict related with the hourly pedestrian volume and average pedestrian delay convened from all studied parameters (average spot speed, approach width, hourly traffic volume, average walking speed, average pedestrian delay and exit stop line).

**Keywords:** Pedestrian, Safety, Conflict, Pedestrian Delay, Improvement pedestrian safety

العوامل المؤثرة على السلامة المرورية للسابلة في التقاطعات الغير مسيطر عليها  
بالإشارة الضوئية

الخلاصة

تناول هذا البحث دراسة عدد من العوامل التي تؤثر على السلامة المرورية للسابلة مستخدماً تقنية التعارضات المرورية. تم الإستناد على توصيات الـ FHWA في عملية جمع البيانات التي طبقت على أربعة تقاطعات غير مسيطر عليها بالإشارة الضوئية ودرجة من ناحية الحجم المروري العالي وعدد السابلة العالي في مركز مدينة بغداد.

تم استخدام تحليل الإنحدار لربط التعارضات المرورية الساعية للسابلة مع كل من الحجم المروري الساعي للسابلة وكذلك لمعدل سرعة السير للسابلة بالإضافة إلى ربطها مع كل من معدل سرعة السير للمركبات ومعدل زمن التوقفات للسابلة. دليل السعة المرورية 2000 استخدم لإيجاد معدل زمن التوقفات للسابلة. بعض الإقتراحات بإجراء معالجات لخصائص التصميم الهندسي لتحسين السلامة المرورية للسابلة.

بين النموذج الإحصائي المستحدث بأن هناك زيادة إضافية للتعارضات المرورية الساعية للسابلة وبمنحنى أسّي موجب بالعلاقة مع الحجم المروري للسابلة، الحجم المروري للمركبات، سرعة سير المركبات وزمن التوقفات للسابلة وبمعامل ارتباط يتراوح بين 0.824-0.949، وكذلك بين النموذج الإحصائي المستحدث بأن هناك نقصان إضافي للتعارضات المرورية الساعية للسابلة وبمنحنى أسّي سالب بالعلاقة مع معدل سرعة سير المركبات وبمعامل ارتباط 0.921. ومن الناحية الأخرى بين النموذج الإحصائي المستحدث بأن هناك زيادة للتعارضات المرورية الساعية للسابلة بالنموذج الخطي الإيجابي بالعلاقة مع عرض المقترب وبمعامل ارتباط 0.837 بالإضافة إلى ذلك تم التوصل إلى إن أعلى قيمة لمعامل الارتباط 0.943 عند حساب التعارضات المرورية الساعية للسابلة للسابلة بدلالة الحجم المروري للسابلة مع زمن التوقفات للسابلة من بين العوامل التي درست (معدل سرعة السير، عرض المقترب، الحجم المروري للمركبات، معدل سرعة سير السابلة، معدل زمن التوقفات ووجود خط الوقوف)

## 1. Introduction

In 2004, the National Highway Traffic Safety Administration (NHTSA) reported that 68,000 pedestrians were injured in traffic collisions. In 2005, 4,881 pedestrians died as a result of being struck by automobiles (up from 4,641 in 2004), accounting for more than 10 percent of total traffic-related fatalities (NHTSA 2006). As well as in a study of 5,797 pedestrian fatalities, 38.1 percent were attributed to pedestrians crossing the roadway (NHTSA, 2004) [1].

Traffic safety is commonly measured in terms of the number of traffic accidents and the consequences of these accidents in terms of severity. While this historical data approach is useful for the identification of safety problems, it is regarded as a 'reactive' approach implying that a significant number of accidents must be recorded before a decision could be taken. A further drawback with this approach concerns the quality and availability of accident data. In order to perform a

different form of safety analysis, the use of Surrogate Measures of safety has been suggested as an alternative to accident data analysis. To be useful for transportation safety applications, a surrogate measures technique should satisfy two conditions (Tarko et. al., 2009) [2]:

1. A measurable or observable non-crash event that is physically related in a predictable and reliable way to crashes, and
2. A practical method for converting or calibrating the non-crash event into a corresponding crash frequency and/or severity.

About the second condition, there is a lack of knowledge for converting the results into either crash frequency or severity. The Traffic Conflict Technique (TCT) is perhaps the most developed indirect method of safety surrogate measure. The technique itself is grounded in the ability to register the occurrence of near accidents directly in real-time traffic and therefore offers a faster and, in

many aspects, more representative way of estimating expected accident frequency and accident outcomes. The concept of traffic conflicts was first introduced in 1968 during the ICTCT meeting (International Co-operation on Theories and Concepts in Traffic Safety) in Oslo, as: "A traffic conflict is an observable situation in which two or more road users approach each other in space and time to such an extent that there is risk of collision if their movements remain unchanged".

## 2. Litretuer Review

Several studies looked into the effects of road design characteristics such as street width, intersection locations, and the presence of crosswalks, sidewalks, and traffic signals on injury severity. The width of a street was found to be positively related to pedestrian collision severity (Zajac and Ivan, 2003)[3].

A Washington state study indicates that the number of collisions was higher in urban areas, but the collisions were perhaps more severe in rural locations (Mueller, and Bergman, 1988) [4].

The severity of injury in collisions occurring at the intersections of two-lane roads was found to not differ significantly whether crosswalks were marked or unmarked (Zegeer, 2002)[5].

Pavement markings may reduce crashes involving roadside pedestrians and disabled vehicles. Roadway markings, especially pavement edge markings, are frequently not present at pedestrian/vehicle crash sites. Pavement edge markings help the pedestrian and vehicle stay on the appropriate travel ways (I. I. H. S, 1997) [6].

In a 2002 study by the Highway Safety Research Center (HSRC), the authors found the crash experience of marked versus unmarked crosswalks at 1,000 locations in 16 states comparable with the San Diego results. The authors found that the risk of a pedestrian-vehicle crash was 3.6 times greater at uncontrolled intersections with a marked crosswalk than with an unmarked crosswalk and the pedestrian crossing improvements are needed (Zegeer, 2002) [7].

However, on multi-lane roads fatal pedestrian collisions were found to be more frequent at marked than at unmarked crosswalks. A Swedish study found that on streets with a posted speed of under 30 km/h, marked crosswalks increased vehicular yield rates for pedestrians. Speed cushions situated at a two-car-length distance from the marked crosswalk was also found to increase yield rates for pedestrians and cyclists in comparison to speed cushions located closer to the marked crosswalk (Leden, 2006)[8].

## 3. Pedestrian Delay

Depending on the research, pedestrian delay can have different definitions. Most of the studies reviewed defined delay as the amount of time between the point at which a pedestrian arrives at the curbside and the point at which he or she steps off the curb as well as any time that the pedestrian has to wait in the roadway for acceptable gaps in the traffic. One major difficulty with this definition is determining when a pedestrian "arrives" at the curbside. For instance, a pedestrian may walk straight to the curb and then look for a gap in the traffic or he/she may begin to watch for a gap long before stepping up to the curb. In the latter

case, the pedestrian can adjust his or her walking speed in which to arrive at the curb at the instant a gap is available in the traffic.

The Highway Capacity Manual includes average delay to pedestrians at unsignalized intersections as the measure of level of service (LOS) that suggests delay to pedestrians at unsignalized intersections should be considered congruent to delay to vehicles on the cross street at unsignalized intersections (HCM,2000) [9].

#### 4.Improvement Pedestrian Safety

A 2003 study published in the American Journal of Public Health found three categories of road design improvements that can reduce pedestrian accidents( TRB, 1997) [10]:

1. Separate pedestrians and vehicles: Pedestrians and vehicles don't mix. By creating structures and systems to keep them apart, we keep pedestrians safer.
2. Increase the visibility of pedestrians.
3. Reduce vehicle speeds in areas where there are likely to be pedestrians.

National cooperative highway research program suggested that roadway narrowing can be used for lowering vehicle speeds and increasing safety in the areas around pedestrian crossings, as well as redistributing space to other users. Narrowing can occur at selected locations along a corridor or over the entire corridor itself. The physical and visual characteristics of the roadway narrowing encourage drivers to reduce their speeds, which can facilitate pedestrian traffic in the area (Nazir & Dominique,2006) [11].

FHWA recommended about Markings Guidelines: Marked crosswalks alone should not be installed at unsignalized pedestrian crossings when speeds are greater than 40 mph.

Several evaluations have tested a combination of crossing treatments and found these treatments to be more effective when used together systematically. For example, a study in St. Petersburg, Florida, found that advanced yield lines, yield here to Pedestrian signs, and pedestrian prompting signs were most effective when used together (Hugo & Luiz, 2005) [12].

#### 5. Data Collection

According to the definition of U.S. FHWA-Federal Highway Administration guides, the video data are recorded to identify all types of pedestrian conflicts, pedestrian volume , traffic volume, (all referred to a standard 8 hour period of a week day) as well as the spot speed of vehicles and the approach width are measured at four unsegnalized intersections in CBD area in Baghdad city at 2010 and this intersections are :

1. AL- Jaderea intersection.
2. AL- Mesbeh intersection.
3. 14 Ramdan intersection.
4. AL- watheq intersection.

#### 6. Pedestrian Conflict Type

Figure (1) show the eight types of pedestrian conflict where recorded in unsegnalized intersections depending on the definition of U.S. FHWA-Federal Highway Administration as fellows :-

1.  $P_{c1}$  : It is the pedestrian who crossing from right of straight vehicle, near crossing approach.
2.  $P_{c2}$  : It is the pedestrian who crossing from left of straight

vehicle, near crossing approach.

3.  $P_{c3}$  : It is the pedestrian who crossing from right of straight vehicle far crossing approach.
4.  $P_{c4}$  : It is the pedestrian who crossing from left of straight vehicle far crossing approach.
5.  $P_{c5}$  : It is the pedestrian who crossing to frontal path from right turning vehicle.
6.  $P_{c6}$  : It is the pedestrian who crossing to back path from right turning vehicle.
7.  $P_{c7}$  : It is the pedestrian who crossing to frontal path from left turning vehicle.
8.  $P_{c8}$  : It is the pedestrian who crossing to back path from left turning vehicle

Table (1) explain the hourly pedestrian conflict and some of the geometric parameters influence pedestrian safety at the studies intersection.

### 7. Data Analyses

Pedestrian conflicts at each approach are obtained due to different type of pedestrian conflict. A worksheet of HCM 2000 is used to determine the average pedestrian delay for all approaches in the studies intersections to estimate the pedestrian safety by developing model correlates hourly pedestrian conflict to average pedestrian delay , Table (2) summarized the result as well as Figure (3) shows the exponential model with coefficient of correlation (0.95) of hourly pedestrian conflict in relation with hourly pedestrian volume and Figure (4) show the exponential model with coefficient of correlation (0.89) of hourly pedestrian conflict in relation with hourly traffic volume as well as Figure (5) explain the negative exponential model with coefficient of

correlation (0.92) of hourly pedestrian conflict in relation with average pedestrian walking speed, Figure ( 6) show the exponential model with coefficient of correlation (0.82) of hourly pedestrian conflict per approach in relation with average spot speed and Figure (7) explained linear model with coefficient of correlation (0.84) of hourly pedestrian conflict per approach in relation with approach width finally Figure (8) show exponential model with coefficient of correlation (0.86) of hourly pedestrian conflict in relation with average pedestrian delay.

The resulting statistical analysis of regression models obtained by ( STATISTICA software ) are show in table (3) as well as the parameters of the statistical model are show in this table .

### 8. Suggested Countermeasures To Improve Pedestrian Safety

1. Change the location of stop line of vehicles or marking line of pedestrian to increase the visibility to pedestrian as shown in figure (9).
2. From figure (6) by limiting the spot speed at 35 kph ,the hourly pedestrian conflict reduce to 20 this mean the percent of reduction in hourly pedestrian conflict is 60.6%.
3. Approach narrowing can be used for lowering vehicle speeds and increasing safety in the areas around pedestrian crossings, from figure (7) the percent of reduction in hourly pedestrian conflict is 40% when narrowing the approach width by 1 ft.

4. Crosswalk lines should extend across the full width of pavement. Crosswalks should be marked at all intersections with “substantial conflict” between vehicles and pedestrians. Crosswalks should be no less than 6 ft (1.8 m) wide (AASHTO, 2001)[13].

### 9. Conclusions

1. The results show that:-

§ The positive exponential relationship between hourly pedestrian conflict and hourly pedestrian volume with coefficient of correlation ( $R^2=0.949$ ). The exponential model reveals that extra increase in hourly pedestrian conflict may be resulted due to farther increase in hourly pedestrian volume.

§ The positive exponential relationship between hourly pedestrian conflict and hourly traffic volume with coefficient of correlation ( $R^2=0.889$ ). The exponential model reveals that extra increase in hourly pedestrian conflict may be resulted due to farther increase in hourly traffic volume.

§ The negative exponential relationship between hourly pedestrian conflict and average pedestrian walking speed with coefficient of correlation ( $R^2=0.921$ ). The exponential model reveals that extra decrease in hourly pedestrian conflict may be resulted due to farther increase in pedestrian walking speed.

§ The positive exponential relationship between hourly pedestrian conflict per approach and average spot speed with coefficient of correlation ( $R^2=0.824$ ). The exponential model reveals that extra increase in hourly pedestrian conflict may be resulted due to farther increase in spot speed.

§ The positive linear relationship between hourly pedestrian conflict per approach and approach width with coefficient of correlation ( $R^2=0.837$ ). The linear model reveals that the increase in hourly pedestrian conflict may be due to the unacceptable speed of drivers not allow to the pedestrian to safe cross the approach with its width.

§ The positive exponential relationship between hourly pedestrian conflict and average pedestrian delay with coefficient of correlation ( $R^2=0.859$ ). The exponential model reveals that extra increase in hourly pedestrian conflict may be resulted due to farther increase in pedestrian delay.

§ The higher coefficient of correlation (0.943) well get it when pedestrian conflict related with the hourly pedestrian volume and average pedestrian delay convened from all studied parameters, this may be due to the higher effect of this tow parameters studied.

2. The primary advantage of TCT is that conflicts occurred much more frequently than accidents. The conflict method provided a clearer picture of the initial causes of the accidents, something often lacking from accident reports. Furthermore TCT may provide information on relative risks to diagnose the types of problems at a particular location, and it represents an easy and efficient tool to check location safety issues when there is limited or no crash data, that well be traffic conflict technique is a good tool to evaluate pedestrian traffic safety.

3. Some countermeasures strategies are suggested to improve pedestrian traffic safety as recommended in paragraph 9.

## 10. References

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**Table (1) Summary of Collected all Types of Hourly Pedestrian Conflict & Geometric Characteristics of Studies Intersections**

Intersections	HPC /App.	HPC/INT.	ASS kph	AW(m )	ESL	VESL*	
A App.Di.	SB	33	180	37.9	7.5	ESL	NV.
	NB	61		50.5	8.4	ESL	NV.
	EB	49		47.7	8.4	ESL	NV.
	WB	37		43.2	7.5	ESL	NV.
B App.Di.	SB	90	351	52.3	10.5	No SL.	NV.
	NB	81		51.9	10.2	No SL.	NV.
	EB	75		50.9	10.2	No SL.	NV.
	WB	105		52.7	10.5	No SL.	NV.
C App.Di.	SB	41	156	46.8	7.5	ESL	NV.
	NB	39		46.8	8.4	ESL	NV.
	EB	53		49.2	8.4	ESL	NV.
	WB	23		34.3	7.5	ESL	NV.
D App.Di.	SB	34	266	40.9	7.5	No SL.	NV.
	NB	82		52.1	9.6	No SL.	NV.
	EB	97		52.5	9.6	No SL.	NV.
	WB	53		49.8	7.5	No SL.	NV.

App.Di : Approach direction.  
 HPC/A : Hourly pedestrian conflict per approach.  
 HPC/I : Hourly pedestrian conflict per intersection.  
 ASS: Average spot speed (kph).  
 AW : Approach width (m).  
 ESL: Exit stop line.  
 VESL : Visibility of exit stop line.  
 \* : See figure (2).  
 NV : Not visible stop line.

**Table (2) Summary of Studies Parameters influence pedestrian safety**

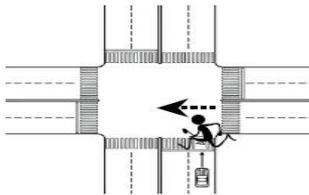
Intersections	A	B	C	D
HTV	6400	6888	5987	6768
HPV	1233	1532	1098	1456
HPC / I	180	351	156	266
APWS	0.87	0.65	1.1	0.73
APD (s)	59	68	50	64

HTV : Hourly traffic volume.  
 HPV : Hourly pedestrian volume.  
 HPC/I : Hourly pedestrian conflict per intersection.  
 APWS : Average pedestrian walking speed  
 APD : Average pedestrian delay (s).

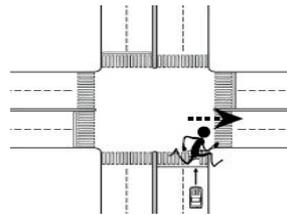
Table (3) Developed models relate hourly pedestrian conflict to Studies Parameters influence pedestrian safety

Developed Model	R	R <sup>2</sup>	Standard Error	P-value
$HPC = 1E-05 HPV 2.3502$	0.9740	0.9487	5.001	4.558E-05
$HPC = 2E-19 HTV 5.5125$	0.9433	0.8898	3.976	7.59E-04
$HPC = 166.69 APWS -1.5487$	0.9597	0.9211	4.213	3.22E-06
$HPC/App. = 0.0003 ASS 3.1818$	0.9076	0.8237	3.125	3.578E-06
$APC/App. = 19.458AW - 109.73$	0.9151	0.8374	2.291	6.79E-07
$HPC = 0.0061APD 2.5695$	0.9273	0.8598	4.897	2.002E-05
$HPC = -388.359 + 0.509 HPV + 0.480 APD$	0.9711	0.9430	8.242	1.000E-05

HPC : Hourly pedestrian conflict.  
 HPV : Hourly pedestrian volume.  
 HTV : Hourly traffic volume.  
 APWS : Average pedestrian walking speed.  
 ASS. Average spot speed (kph).  
 AW : Approach width (m).  
 APD : Average pedestrian delay (s).

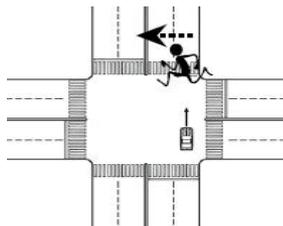


$P_{c1}/TPd$ : pedestrian from right of,

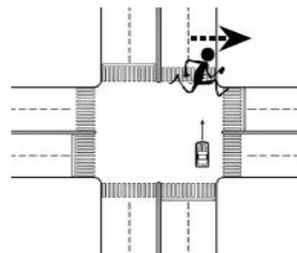


straight vehicle near crossing

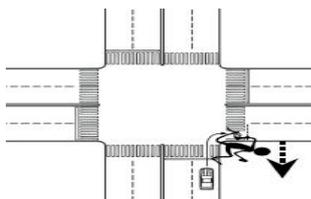
$P_{c2}/TPE$ : pedestrian from left of straight vehicle, near crossing



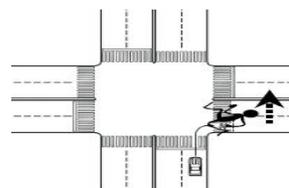
$P_{c3}/TPd$ : pedestrian from right of, straight vehicle far crossing



$P_{c4}/TPE$ : pedestrian from left of straight vehicle, far crossing



$P_{c5} /TDF$ : pedestrian to frontal path from right turning vehicle



$P_{c6} /TDR$ : pedestrian to back path from right turning vehicle

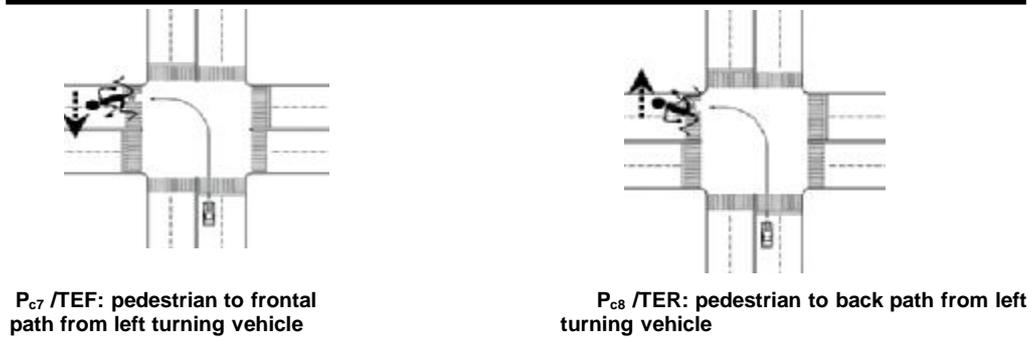


Figure (1) Pedestrian -Vehicle Conflict Types in Intersection Crossings

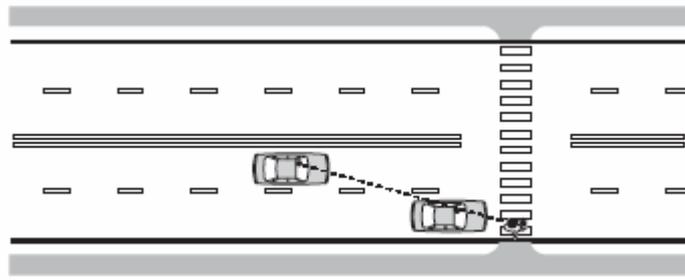


Figure (2) Not Visible Stop Line to Pedestrian

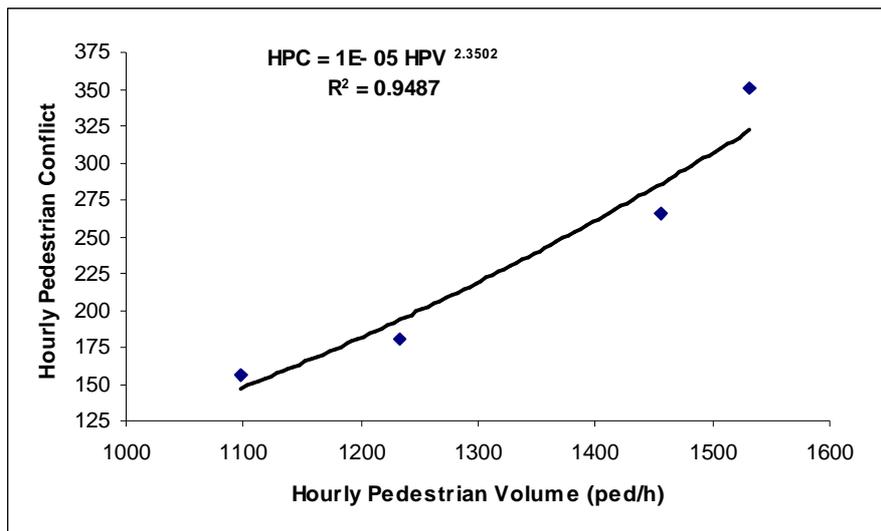


Figure (3) Exponential relationship between hourly pedestrian conflict & hourly pedestrian volume

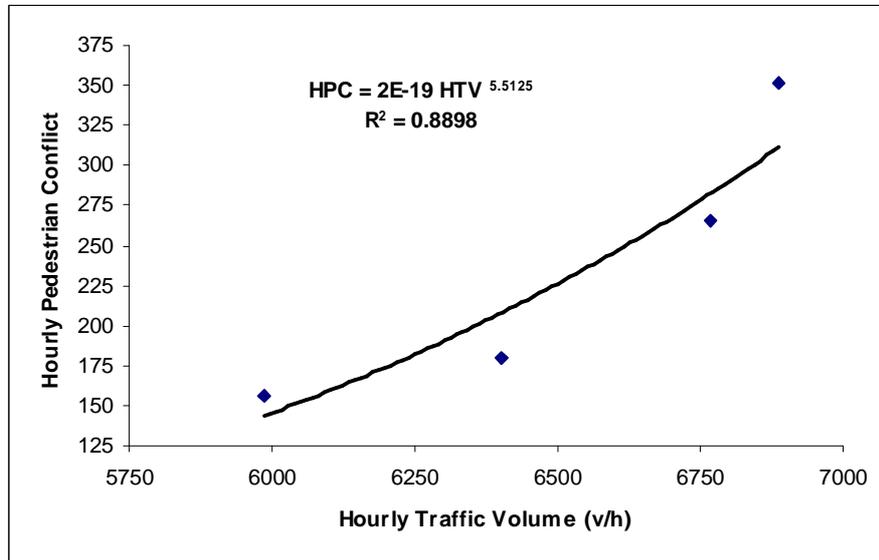


Figure (4) Exponential relationship between hourly pedestrian conflict & hourly traffic volume

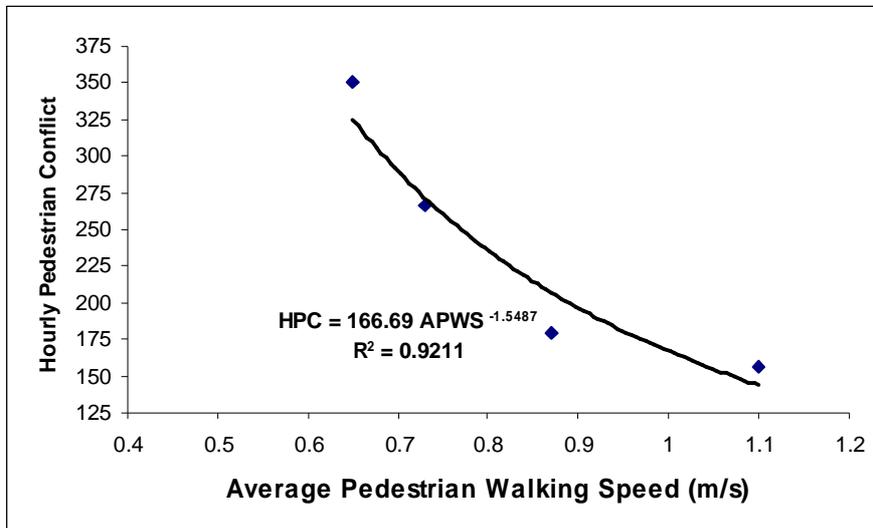


Figure (5) Exponential relationship between hourly pedestrian conflict & average pedestrian walking speed

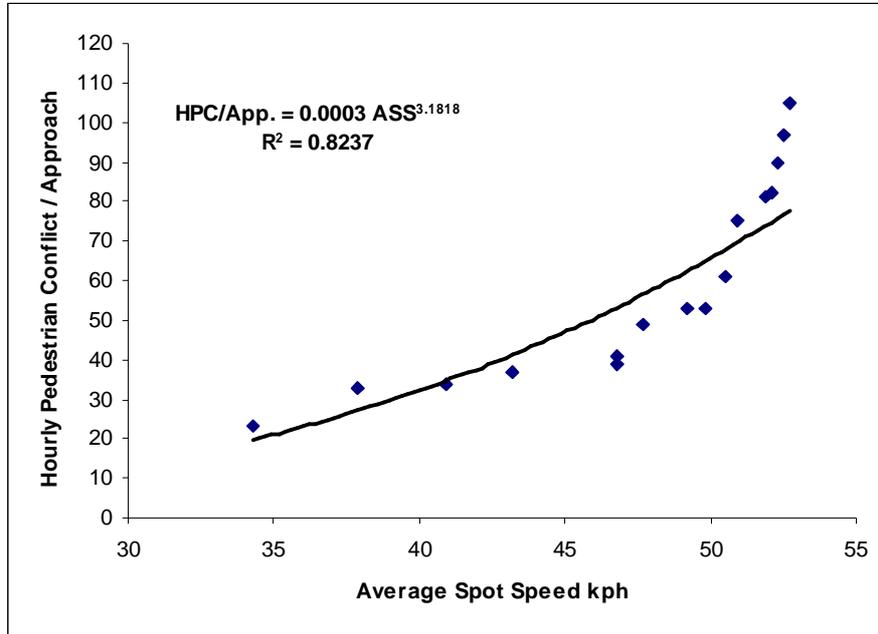


Figure (6) Exponential relationship between hourly Pedestrian conflict / approach & average spot speed

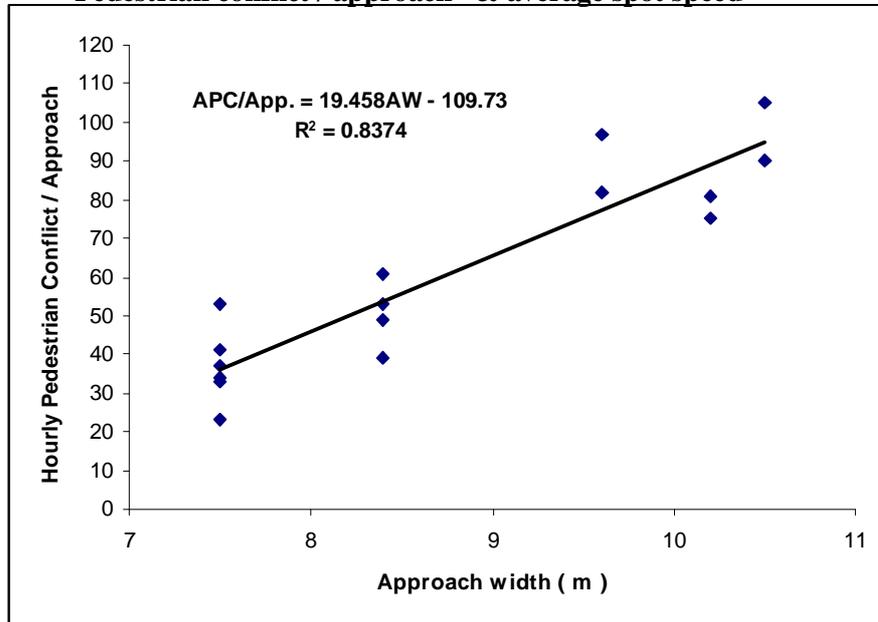


Figure (7) Linear relationship between hourly pedestrian conflict / approach & approach width

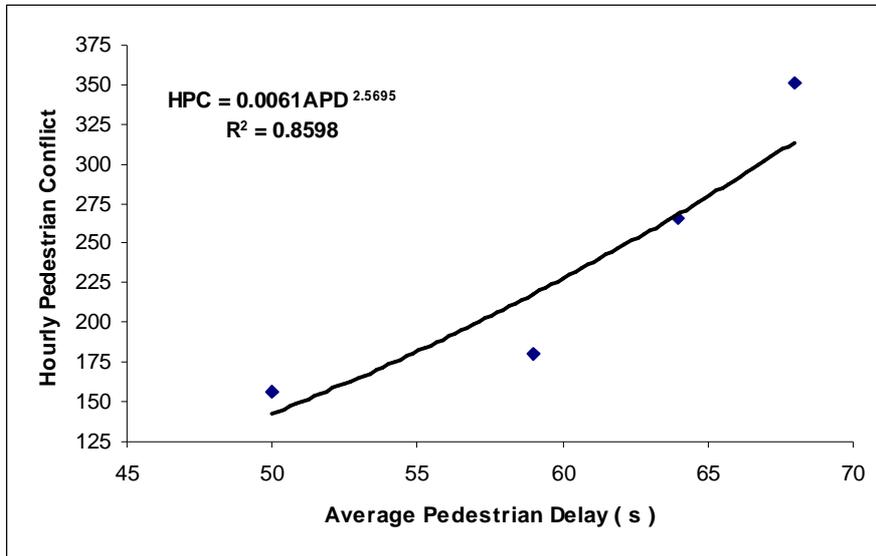


Figure (8) Exponential relationship between hourly pedestrian conflict & average pedestrian delay

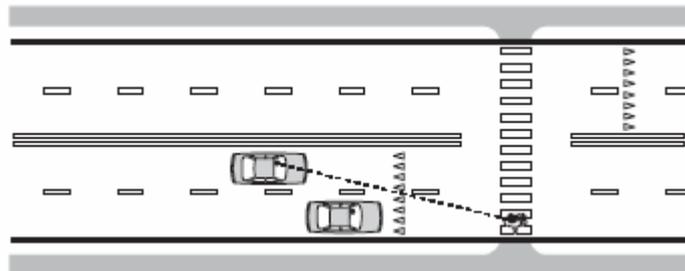


Figure (9) Increasing the Visibility to Pedestrian